The investigation of regularities of the memristor effect of oxide nanosized titanium structures from the parameters of local anodized oxidation

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One of the priorities for the development of modern nanoelectronics is the development and study of nonvolatile memory elements with high speed. At present, a promising element for creating such a RAM is a memristor, an element of nanoelectronics, whose resistance changes when an external field is applied. A characteristic feature of the memristor is its ability to maintain the value of resistance after the cessation of the external field.

At the same time, an urgent task is to study the patterns of formation of oxide nanoscale structures (ONS) of titanium by the method of local anodic oxidation (LAO) and the manifestation of the memristor effect in them. Therefore, the aim of the work is to study the effect of relative humidity in the chamber on the production of ONS of titanium by the LAO method, exhibiting a memristor effect.

To carry out experimental studies, a thin titanium film 19 ± 0.5 nm thick, obtained on the surface of the SiO2/Si structure using magnetron sputtering on a multifunctional Auto 500 installation (BOC Edwards, England), was used as the initial substrate. Then, an LAO titanium film with NSG10 brand cantilevers with a conductive Pt coating was carried out using a Solver P47 Pro scanning probe microscope (NT MDT, Zelenograd, Russia), by scanning atomic force microscopy in 3 × 3 μm areas in a semicontact mode, when applied to the probe system substrate voltage pulses with an amplitude of 10 V, with a probe displacement speed of 3 μm/s. The relative air humidity was 30 ± 1% and 90 ± 1%.

An analysis of the experimental results reflects that with increasing of the relative humidity from 30 to 90%, with LAO, there was a change in the mechanism of resistive switching of the ONS of titanium (Fig. 1). At 30% air humidity the resistance switching of the ONS of titanium proceeded through a mechanism based on the modulation of the Schottky barrier width at the metal/oxide boundary due to the redistribution of oxygen vacancies in the oxide volume. This mechanism can be implemented in the presence of a sufficient number of oxygen vacancies in the oxide volume, which is confirmed by theoretical calculations presented in the first paragraph. The switching mechanism of the resistance of the ONS of titanium obtained by the LAO method at 90% air humidity corresponds to the formation of a conducting channel in the oxide volume, which is possible in case of uneven distribution of oxygen vacancies in the oxide volume in the presence of an area with a low concentration of vacancies which the conducting channel passes through.

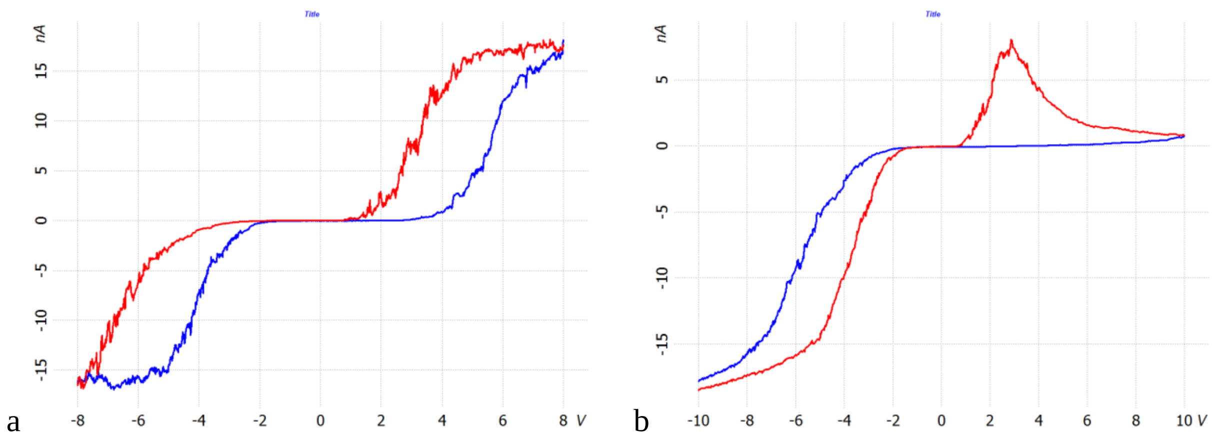

Figure 1. Voltage-current characteristics of ONS titanium obtained at a humidity level in the process chamber (a) 30% and (b) 90%.

Thus, it was shown that the control parameters of the LAO affect the distribution of oxygen vacancies in the volume of the formed ONS, which in turn determines the switching mechanism of the resistance of oxide nanoscale structures of titanium.

The results obtained can be used in the development of technological processes for manufacturing elements of micro- and nanoelectronics based on titanium oxide nanoscale structures by the method of local anodic oxidation.

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